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ABSTRACT

The Zimbabwe Secondary School Science Project (ZIM-SCI) developed student study guides, corresponding teaching guides, and science kits for a low-cost science course which could be taught during the third year of secondary school without the aid of qualified teachers and conventional laboratories. This ZIM-SCI study guide is a four-part unit providing activities and experiments which build on concepts about particles learned in ZIM-SCI units C1 ("What is Water?") and C2 ("Particles in Action"). The material included expands students' knowledge to cover requirements of the O-Level General Science Syllabus. Part 1 focuses on elements, compounds, and mixtures, with references to basic concepts taught in units C1 and C2. Part 2 deals with particulate structure in matter with reference to Brownian motion. The concept of electrostatics is introduced in part 3 to get across the idea of matter being made up of tiny charged particles (ions). Protons and neutrons are also introduced. Part 4 deals with various aspects of chemical bonding. Actual O-level examination questions (with answers) as well as information on principles behind the activities and experiments are provided. (JN)

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ZIM-SCI

ZIMBABWE SECONDARY SCHOOL SCIENCE PROJECT

YEAR 3

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STUDY GUIDE UNIT 2

ATOMS and MOLECULES

SE 043984

UNIVERSITY OF ZIMBABWE
AND MINISTRY OF EDUCATION AND CULTURE

VOL 2

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AUGUST 1983

ZIM-SCI

Zimbabwe Secondary School Science Project

GENERAL SCIENCE

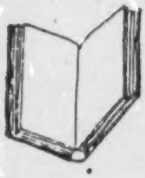
STUDENTS: Please read this carefully. It will help you.

How you will study

This study guide comes to you with a kit of apparatus. Both things are part of a study programme leading you to an understanding of aspects of science. In this course you will be carrying out experiments. The study guide will help you to understand the scientific principles behind the experiments.

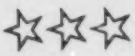
Your work should be done as you are instructed, either by the teacher or the study guide.

To help you to see quickly what you must do, the study guide uses these symbols.



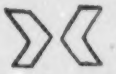
"Read and revise your notes and study guide."

E.Q. "Examination Questions" from past papers.



"Take note of an important point that you should learn."

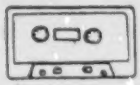
"Activity". This symbol will appear whenever you are asked to do something without your apparatus.



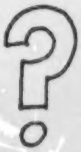
"Summary." This is to help you to go over what you have learned.

"Written work." This is when you must answer questions in writing.

"Experiment." When you see this sign, read the instructions carefully from beginning to end before you start to do the experiment.

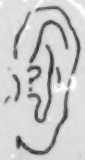


"Cassette Program". To give extra background information.



"How much do you know?" This is for you, to help you to test whether you are remembering what is important.

"Project". A chance to apply your knowledge.



Listen to the teacher and discuss the topic with him/her.

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ATOMIC UNIT 2

Aims of this Unit

When you have completed this unit, you will be able to:

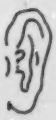
1. State the three states of matter.
2. Describe matter in terms of the Kinetic Theory.
3. Explain what happens when a chemical reaction takes place.
4. Describe the differences between an element, a mixture and a compound.
5. Explain diffusion.
6. Describe osmosis.
7. Explain the structure of an atom.
8. Explain the difference between electrostatic and current electricity.
9. Define:-
   - An electron
   - Proton
   - Neutron
   - Electron shell
   - Atomic number
   - Atomic mass
   - Valency
   - Isotope
   - Molecule
10. Explain radiation in simple terms.
11. Read the Periodic Chart.
12. Explain Electrovalent of Ionic Bonding.
13. Explain Covalent Bonding.

"O"-Level Unit 2

Part 1

ELEMENTS, COMPOUNDS AND MIXTURES

In Unit C, you learnt something about elements, compounds and mixtures.



Tell your teacher the main differences between the three substances above.

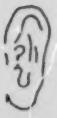
In this unit you are going to learn more about elements. It is important for us to have this kind of knowledge because it forms the basis for the chemistry that is useful in the home, in hospitals and in industry.

In the same Unit C1 you were told something about chemical and physical changes. Below is the summary of these changes.

	Physical Change	Chemical Change
1.	Produces no new kind of substance.	Always produces a new kind of substance.
2.	Is generally easily reversible.	Is generally not easily reversible.
3.	Is not accompanied by great heat change.	Is usually accompanied by considerable heat change.

Now do Exercise 1. in your Exercise books.

Given a mixture of sand and water you can seperate these easily. You did just that in Unit C1.



This time if you were given a mixture of iron filings, sand and salt tell your teacher how you would go about seperating the 3 substances.

You have extracted chlorophyll before in Unit G1. If you have forgotten here is how you do it.

Activity 1 To extract chlorophyll

You need:

your evaporating dish
some green leaves
some methylated spirit
burner
boiling tin
small plastic bottle
a clean stone.

a) Cut up leaves and them in an evaporating dish.

b) Grind the leaves with a stone.

c) Place the ground-up leaves into your boiling tin.

d) Carefully place about 20ml of methylated spirit INTO the boiling tin containing the leaves.

e) Heat the contents in the tin (do not expose methylated spirit to open flame) until you have a nice green solution of chlorophyll extract.

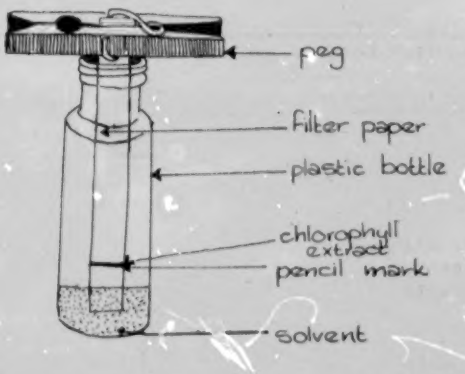
Now with your chlorophyll extract carry out the experiment below.

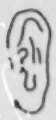
EXPERIMENT 1 : CHROMATOGRAPHY

You need:

filter paper
small plastic bottle
dropper
peg.

1. Cut up a strip of filter paper 1cm wide by 8cm.
2. On the strip of filter paper mark a pencil line about 1,5cm from the end.
3. Apply the chlorophyll pigment to this line by means of a dropper.
4. Allow the pigment to dry thoroughly by waving the strip of paper in the air and repeat this procedure several times until a very dark green line is obtained.
5. Pour a small quantity of solvent (fresh methylated spirit) in a small plastic bottle.
6. Gently lower the filter paper strip into the small bottle allowing only 1cm of the end of the paper to dip into the solvent.
   Make sure that the paper does not touch the sides of the bottle by holding it with a peg as in diagram below.
7. Leave the set-up for 15 minutes then write all you observe.





Discuss with the rest of the class your observations and conclusions of the above experiment.

If you had carried out the experiment correctly you should have noticed that the solvent (Methylated Spirit) moves up the filter paper as soon as you dip the paper into the spirit. As it does so the green chlorophyll partially dissolves and a faint coloured line follows the solvent up the strip of paper. If you look closely at this coloured line you will discover that there are different colours on the filter paper varying from deep green to yellow, brown and purple.
Where do you think these colours came from?

These are the different pigments that make up the chlorophyll. Chlorophyll is therefore a mixture of differently coloured pigments and in this experiment we have succeeded in seperating them.

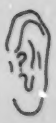
So you can see that there are many ways of seperating substances. In the above experiment we used a method called chromatography.

Seperating substances by Chromatography

Chromatography, which means "colour writing", is a process for the seperation of a mixture of substances by their different rate of movement over a porous medium caused by a moving solvent.

When paper is used i.e. paper chromatography the medium is filter paper.

Paper chromatograph can be used to seperate and analyse even a few microgrammes of a complex organic mixture e.g. of Amino Acids. It can also be used to detect a different ink used by a forger, or to recognise and identify poisons.
Can you think of other substances that can be seperated by chromatograph?



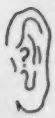
Discuss this with your teacher.

Part 2

PARTICULATE STRUCTURE OF MATTER

Matter

In Unit C1you learned about matter. You have already had evidence from activities and experiments which you carried out in Unit A1 when you melted Nephthalene, and also when in Unit C2 you grew a large crystal of sodium chloride that matter is composed of tiny particles called molecules and atoms.



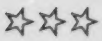
Tell the class another experiment or activity which you carried out previously which shows that matter is made up of very small particles.

All matter exist in one form or the other we call states. There are states of matter.
Can you remember what these states are?

water is an everyday substance that exists in 3 forms or states as follows:

solid - ice
liquid - drinking water
gas - steam

Every substance in the world exists in either one of the three states and many others can exist in all three states. From looking at a solid, a liquid or a gas, what can you say are the differences between them?



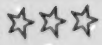
We can say for example that;

A solid has definite size (or volume) and shape.

A liquid has definite size (or volume), but not definite shape.

A gas or vapour has no definite size and shape.

However we can explain the three states of matter in terms of the Kinetic Theory.

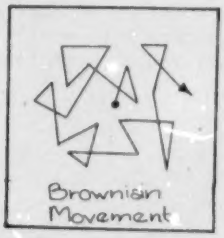


The Kinectic Theory is so named because it starts with that property of the particles which is important to an understanding of the three states of matter, namely, the motion of the particles.

Because the particles are in constant motion, they possess kinetic energy, which tends to keep the particles well spaced out in any substances.

We can do an activity to show that particles that make up matter are in constant but random motion.
Can you remember what we called this phenomenon?

In Unit C2 your teacher showed you the experiment to demonstrate Brownian Motion.



He did this when he placed naphthalene flakes in a plastic bottle containing a mixture of water and methylated spirits then he placed the bottle in strong light.

Through that experiment you learnt something about the behaviour of very tiny particles found in matter.

Based on what we know about the behaviour of these particles we shall now take a closer look at the three states of matter.

SOLID STATE

☆☆☆

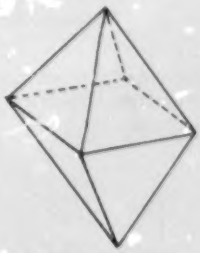
Substances in the solid state are made up of particles (atoms, molecules) which are packed so tightly together as to leave only slight space in the mass of the solid. The particles or molecules are held in regular pattern by strong forces which restrict movement so that a solid has a definite shape. The shape remains fixed unless sufficient force is applied to shatter and distort the solid. Particles in a solid however have a certain amount of vibration.

At the end of Unit C1, you began an experiment to join up particles of sodium chloride into crystals by growing them on a string.
When you examined the crystal with your hand lens, what shape were the crystals?
What name is given to the shape of the sodium crystals?
You also examined and grew copper sulphate crystals.
Were these different from the crystals of sodium chloride?

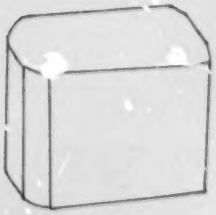
The solid which form crystals consists of particles or molecules arranged in an orderly, packed and repetitive manner. They have therefore geometrical shape, with flat sides as well as sharp edges.

Examples of some crystals:

CUBIC
SODIUM CHLORIDE



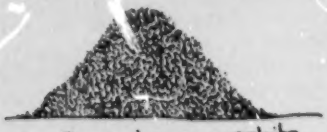
OCTAHEDRON
RHOMBIC
SULPHUR



OCTAGONAL
POTASSIUM PERMANGANATE

MONOCLINIC
SULPHUR

Some solids e.g. charcoal, pitch and glass are non-crystalline or amorphous (of no definite shape). Their particles are arranged in random manner.



Amorphous graphite

THE LIQUID STATE

As you already know, we can change a solid into a liquid by heating.
You did this with napthalene in Unit A1 and C2.
Why do you think heating a solid changes its state to a liquid?

If solids are heated, their constituent particles (atoms or molecules) acquire greater kinetic energy and vibrate more violently.

☆☆☆

Eventually a point is reached when vibration overcomes the binding forces that keep the particles together and the particles become mobile. The crystalline structure then collapses and a liquid state is reached in which the particles have a fair amount of free movement. When a solid changes its state to liquid through heat, this is known as melting.

The temperature at which melting occurs is the melting point (m.p.) of that solid.

Now we shall have a closer look at LIQUIDS.

You have already seen that liquid particles move about more freely than solid particles. They are not packed together so closely and tightly: LIQUIDS are LESS DENSE than solids.
What will happen to the spaces between the particles in a liquid when you heat it?
If we heat a liquid its molecules also acquire increased kinetic energy: they move further and further apart.

What experiment can you carry out that shows that particles of liquid move apart when heated?

Remember the gelatin diffusion experiment in Unit C1?

Your gelatin diffusion experiment showed that there are spaces between the particles of a solid. If your idea of a liquid is correct, then the spaces in a liquid should be bigger than those in a solid because the particles are further apart.

All molecules in a liquid are subjected to forces of attraction from neighbouring molecules. For molecules in a body of a liquid these forces balance each other, but for molecules on the surface there is a resultant attractive force acting downwards. In spite of this some molecules of greater than average energy can escape from the surface of the liquid into the surrounding space and be lost. This liquid is said to have evaporated.

☆☆☆

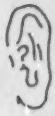
EXPERIMENT 2 : Placing Methylated Spirit on a Hand.

You need:

methylated spirit
straw or dropper

Using a straw or dropper place a drop of methylated spirit on the back of your hand and leave it for a minute or so. What observation do you make besides the fact that the drop eventually evaporates?

You probably noticed that as the spirit evaporated you felt some coldness on the area where the spirit had been placed. Can you think of a reason why there was this drop in temperature on the area?



Discuss this with your teacher.

The temperature at which a liquid substance changes state from liquid to gas after heating is its boiling point (b.p.).

Similarly the temperature at which a solid changes state from solid to liquid is its melting point (m.p.).

Now, is there any need for us to know the melting and boiling points of a substance? To find out carry out the experiment below.

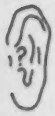
EXPERIMENT 3 Determining the temperature of salted and unsalted water.

You need:

a small boiling tin
water
a thermometer
common salt (sodium chloride)

Place $200cm^3$ of water into your boiling tin. Heat the water to boiling point and notice at what temperature the water boils. Add about 5g of salt. Stir and determine the boiling point.

Repeat this procedure a few times, each time adding exactly 5g salt and noting the b.p. after each addition.



Write down your results and the conclusion you make from the experiment. Now listen to your teacher.

GASEOUS STATE

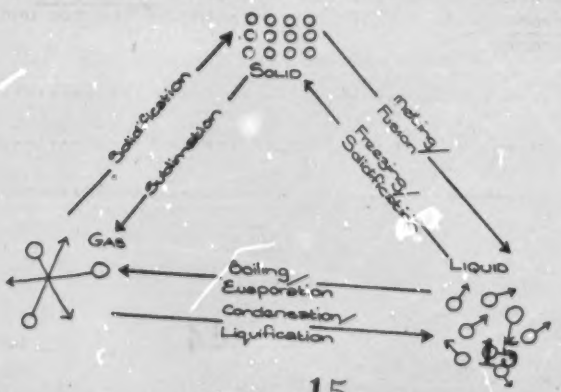
In Unit C2 your teacher placed a few drops of ammonia solution in an evaporating dish in the middle of the classroom. Can you remember the result of that activity?

Any gas consists of a collection of molecules of a particular kind which are in rapid motion. The fact that the molecules are in motion is evident from the fact that a small quantity of a smelly gas such as ammonia or hydrogen sulphide, if liberated at any point in a room, the smell of the gas soon fills that room. Therefore the particles in a gas are free to move.

Here then is a summary of the three states of matter according to the Kinetic Theory of Matter.

SOLID	LIQUID	GAS
Has definite size and shape.	Has definite size but no definite shape.	Has no definite size and no definite shape.
On heating - expands and then changes to liquid.	On heating - expands and then changes to a gas.	On heating - expands very quickly.
Diffuses slowly.	Diffuses fairly fast.	Diffuses very fast.
Particles are closely packed and can only vibrate on one place. Spaces between particles are very small.	Particles are further apart than in a solid. Particles have more freedom of movement.	Particles are very far apart. Particles completely free to move. They have a lot of Kinetic energy.

Since state of matter is dependent on motion and the kinetic energy of the particles, matter can be changed from solid to liquid then to gas and vice versa.



HOW MUCH DO YOU KNOW?

Below are some exam questions.

These questions were taken from past A.E.B. examinations.

Answer these questions in your exercise books and not on the lines below.

E.Q. Answer them as you would do in an actual examination as this would give you practice on how to tackle A.E.B. examination questions.

1. Fig. 1, X and Y represent hydrocarbons.

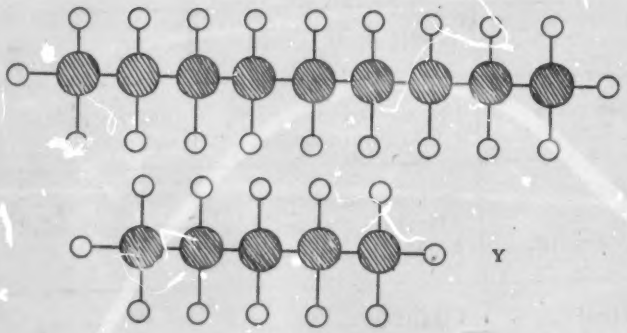


Fig. 1

(a) Which of the two molecules shown has the higher boiling point? Give a reason for your answer.

.....

.....

(b) Distillation can be used to separate a mixture of these two compounds. Explain the meaning of the two underlined terms.

.....

.....

.....

2. Fig. 2 shows the structure of solid sodium chloride.

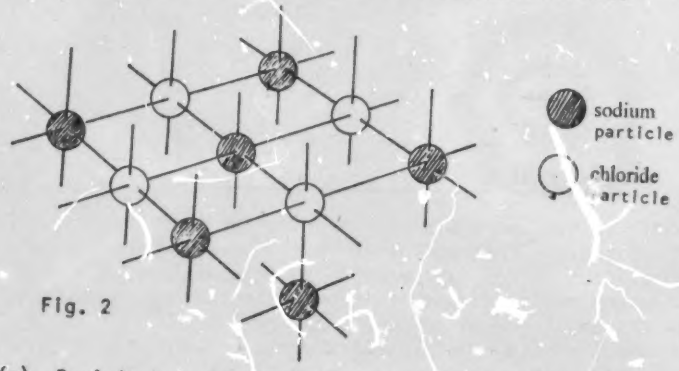


Fig. 2

(a) Explain how the structure of molten chloride would differ from this solid structure.

.....

.....

(b) Why would it be necessary to supply more heat to molten sodium chloride at its boiling point to form sodium chloride vapour at the same temperature?

.....

.....

3. When smoke particles are suitably illuminated and observed through a microscope, they are seen to be moving and changing direction rapidly.

(a) What is the name given to this type of movement?

.....

(b) What causes the smoke particles to change direction constantly?

.....

(c) In general, hot smoke particles rise. What is the name given to the process which causes them to rise?

.....

In Unit C2 you learnt about Diffusion. Can you remember how we defined diffusion? Some examples of diffusion you already know about are copper sulphate crystals dissolving in water Unit C1 and copper sulphate crystals spreading through gelatin in Unit C2.

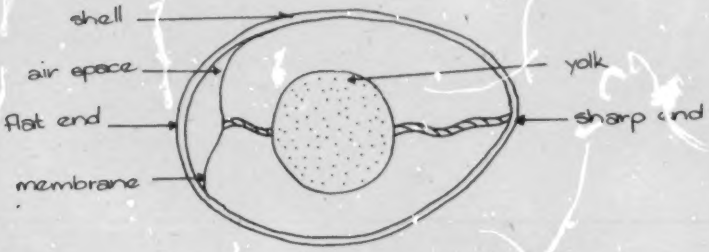
Let us now consider the implication of diffusion with reference to living tissues. All organisms must have adequate water supply and minerals for their function. In Unit G2 you learnt that organic matter is decomposed so that minerals are released into the soil. As you already know these minerals are absorbed by plants from the soil.

How does the water and some of the minerals enter the plant?

In Unit K2 you were told that water can enter or leave a plant cell depending on the circumstances. Words like FLACCID and TURGID were mentioned. Can you remember what these words mean in relation to plant cells?

Also in Unit K a semi-permeable membrane was mentioned, and you also learnt that a force exists which allows liquids of different concentration to move across the membrane.

You are now going to carry out the experiment below, this time using an animal membrane, that of an egg. From Unit E you know that an egg is a big cell with a membrane round it.



EGG

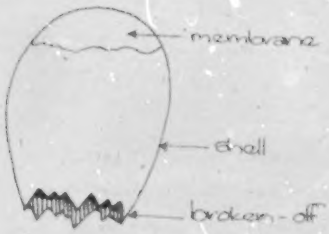
EXPERIMENT 4 OSMOSIS

You need:

2 eggs
2 plastic beakers
sugar
your plastic measures
water.

Open carefully the pointed end of an egg and empty the contents into a cup.

Again carefully remove the shell the size of a one cent piece from the blunt end of the egg, (this end contains the air space) to expose the membrane which separates the shell with the air space. Make sure you don't damage or make a hole in this membrane which you have exposed.

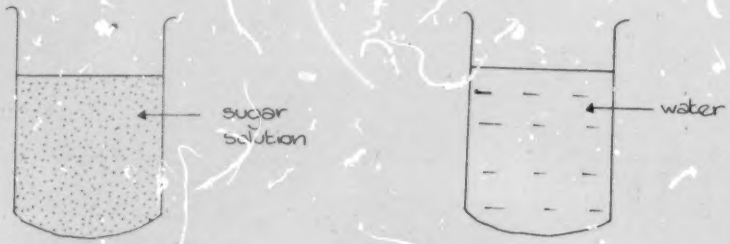


Do exactly the same with the other egg.

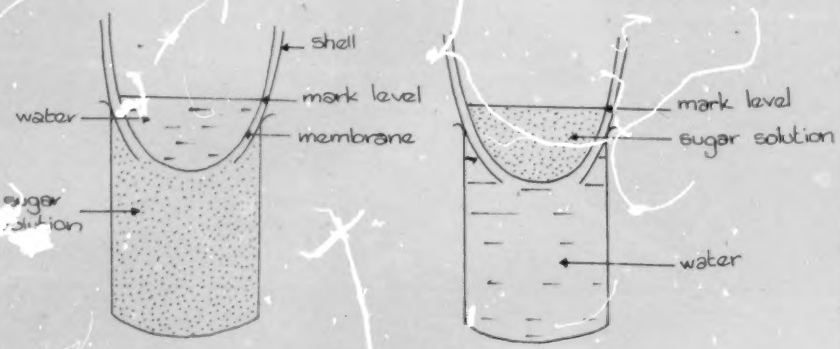
With your sugar make a sugar solution (concentration ratio 3 sugar to 5 water). You can mix three 5 ml measures of sugar to 25 ml of water. Stir until all sugar dissolves.

Place 5 ml of sugar solution into one egg shell and in the other place 5 ml of water. Lightly mark with your pen on the inside of the shells the level of the sugar solution and the water respectively.

In one small plastic beaker put 35 ml of water and in the other one the same amount of sugar solution.

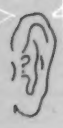


Sit the egg shell containing the sugar solution on to the beaker containing water. Make sure that the membrane is touching the water. Sit the other egg shell containing water on to a beaker containing sugar solution as in the diagram below.



Leave the 2 set up for 20 minutes and make your observations and conclusions.

In Unit K you learnt about Osmosis. You should have realised that the experiment above shows the process of osmosis.



As you already know osmosis is a special kind of diffusion. The egg membrane is the semi-permeable membrane. Can you tell the class what your observations and conclusions were in your experiment?

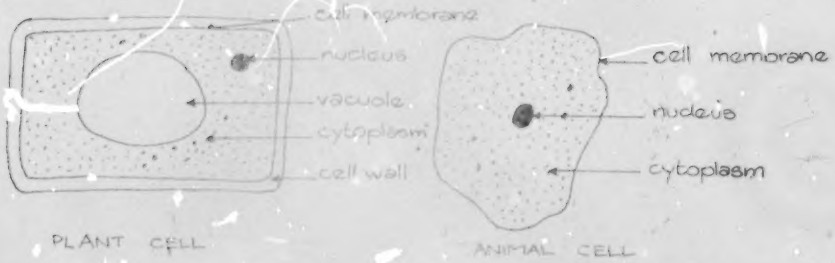
From your experiment you should have observed that the level of liquid in the egg shell containing sugar solution rises while the level of the water in the shell sitting in a beaker with sugar solution falls. In other words the water moves across the egg membrane into the sugar solution.

☆☆☆

The movement of water molecules from a region of high water concentration to a region of low water concentration through a semi-permeable membrane is what osmosis is. The physical seperation of the two liquids of different concentrations by the semi-permeable membrane creates a force which allows water molecules to pass from a region of high water concentration to a region of low water concentration.

In living organisms, solutions of different concentrations are separated by the membranes called CYTOPLASMIC membranes which surround the cells. These membranes are semi-permeable and so permit the passage of water molecules, and certain dissolved substances e.g. mineral salts but do not permit the passage of the large sugar and protein molecules. In a plant, the walls of the root hairs are very thin and semi-permeable and as a result water enters these root hairs by osmosis. This is because the contents of the cells which we call the cell sap forms a much more concentrated solution than the water in the soil which surrounds the root hairs.

Remember in Unit E1 you learnt about the differences between plant and animal cells.



One of these differences is in the size of the vacuole. Plant cells have very large vacuoles, while animal cells have none or very little ones. The vacuoles in plant cells contain dissolved substances which allow water to enter or leave the cell by the process of osmosis.

Now do Exercise 2.

PART 3

ATOMIC THEORY

In this section of the unit you are going to learn about particles called ATOMS. These are the particles that make up the elements. You have heard the word atom before in Unit C2.

When we talk of the smallest particles of elements we call these ATOMS. If you remember from UnitC2 an atom was defined as the smallest particle of an element that can take part in a chemical change.

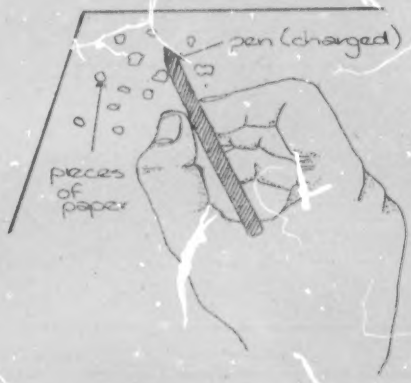
Let us begin by investigating the forces which hold atoms together in the many different substances the world is made.

EXPERIMENT 5 Electric Charges

a) You need:

a piece of paper
a plastic pen or ball point or plastic comb or a plastic rod from the materials kit
balloon .

Tear your piece of paper into small pieces about 5 mm and place these on your desk. Rub your pen or comb a few times vigorously into your hair or with a piece of woollen cloth (your wollen garment will do just as well). Then bring the pen near to the pieces of paper on the desk.



b) Repeat the above procedure this time with an inflated balloon.

WHAT DO YOU NOTICE HAPPENING EACH TIME?

You have on many occasions felt and seen some sparks during the dry season when you removed your wollen clothes at night. Could there be a link between these sparks you feel and see and what you observed happening in the experiment above, what do you think?

Obviously in both cases rubbing or friction is responsible for the attraction of the pieces of paper by the rubbed pen or balloon and the sparks you feel and see.

In Unit 1 (O'Level Forces Unit) you learnt that there is a force that can make your hair get attracted to a jersey as you pull it over your head, and that this force is also responsible for the sparks and the lightning during a storm being attracted to the ground.
Can you remember what we call this force?

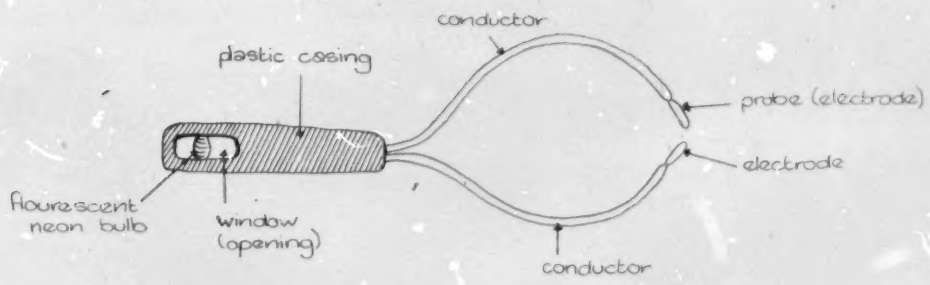
About one hundred years ago scientists discovered that the forces which hold atoms together are closely connected with this electricity. To learn about atoms therefore we need to learn more about electricity first.

If you think further back in Unit 11 you learnt about the flow of electric current and how that current carries energy as it moves along a conductor. Just like water flowing in a bucket it is possible to accumulate electricity in one place. Since the electricity is not moving it is called STATIC ELECTRICITY.

☆☆☆

You were also told that a force is needed to make current electricity flow along a conductor and that this force is supplied by a cell or battery. Similarly a force is also needed to generate static electricity. This force is the FRICTIONAL FORCE produced when two surfaces rub against one another.

Are the energy particles moving in current electricity the same as those stationary in static electricity?
We can find out about this by using an instrument known as a FLUORESCENT NEON-BULB TESTER.



FLOURESCENT NEON-BULB TESTER

ACTIVITY 2 : To use a fluorescent neon bulb tester.

You need:

a balloon
a woollen cloth or your jersey
a string
a neon-bulb tester

Inflate your balloon and tie the opening with a string. Charge your inflated balloon very well. Let one of your classmates hold the neon-bulb tester and let him bring one of its two conductor ends to touch the charged balloon. As the conductor touches the surface of the balloon keep rotating the balloon and watch the fluorescent neon-bulb on the tester. Preferably this activity should be carried out in the dark, but the bulb area could be held over a dark background.

Keep repeating the procedure until you get a definite result and then discuss your observations with your teacher.

When the forces which hold atoms together are made to act on large objects as they did in experiment (a) scientists say the objects are CHARGED. A charged object contains Static Electricity.

Think back to how you produced charges. Perhaps something was rubbed off or on by the frictional force you used? Let us investigate this possibility further:

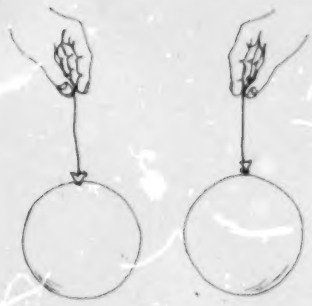
EXPERIMENT 6. To show attraction

You need:

2 balloons
a string
a woollen cloth.

Inflate the two balloons and tie the openings with a string which you can also use to suspend the balloons with.

Suspend one of the balloons by a string. Charge the other balloon by rubbing a few times with your woollen cloth or your jersey. While you are holding this second balloon by the string bring it next to the first one you had already suspended earlier. The balloons should not touch while you are doing this, but let the balloons hang freely and observe (see diagram).



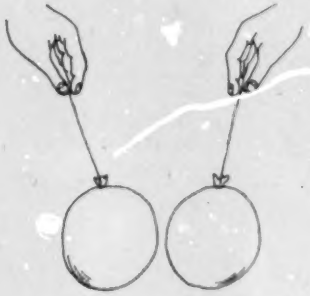
Now allow the balloons to touch each other and rub over each other and observe what happens when they are suspended near each other again.

EXPERIMENT 7 To show repulsion

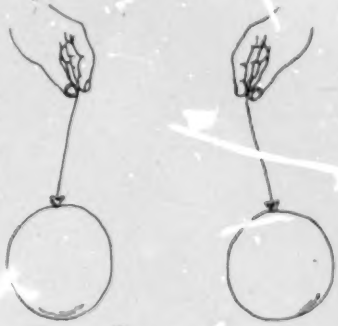
This time charge the balloons again by rubbing with a cloth. Let the 2 charged balloons hang freely next to one another. Do not let them touch.

How do the balloons behave? Write down all your observations.

You might have noticed that when one charged balloon is brought next to the uncharged one there is attraction between them just as your plastic pen attracted the pieces of paper. When the balloons rubbed together the attraction became less or even changed to a REPULSION. When the charged balloons which you had charged in the same way were brought together they also repulsed each other.

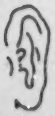


ATTRACTION



REPULSION

Think back to our original idea of something rubbing off in the charging process.
Can you explain what happened to the balloons in this experiment?
Think hard! Discuss your thoughts with your teacher.



You know that unlike poles attract and like poles repel, does this explain the behaviour of your balloons and the charges they carry? Think hard again.

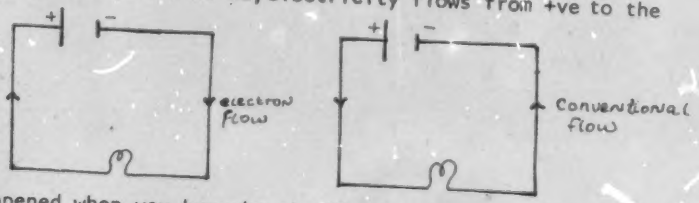
The fact that one balloon attracts the other means that the balloons must carry opposite charges, one positive (+ve) charges, the other negative (-ve) charges. Similarly if the balloons repel, it must mean that both balloons carry like charges, either positive (+ve) or negative (-ve) charges. Electrostatic charges can therefore be positive or negative and there is a force of attraction between them. Rubbing a plastic or polythene surface with a woollen cloth leaves it positively or negatively charged.

☆☆☆

If we think of electricity as very small energy particles, we can explain the difference between charged and uncharged objects on one hand and negatively and positively charge ones on the other. Scientists discovered that a small particle of electricity does exist. They called it the ELECTRON. These particles exist in all matter. They are free to move in conductors and when moving they form the electric current. In insulators, such as rubber or plastic, they are not free to move but can be shifted from place to place by rubbing (frictional force). When bodies are charged it means they either have more than the usual number of electrons or less.

Do you remember in Unit 11 learning about positive and negative terminals on cells and batteries? The electron is negative so a torch cell has more electrons at the negative end than at the positive end. When the two are connected together by a wire the chemical energy in the cell is used to cause the electrons to flow until there are the same number on both ends. When that has happened the cell is 'flat' and useless to us! But when you have a new cell and you make a complete circuit containing a torch bulb, the bulb lights because electrons will be flowing through the circuit from -ve terminal to +ve terminal. However, by convention we say electricity flows from +ve to the -ve.

☆☆☆



What happened when you brought the fluorescent neon-bulb tester to a charged balloon? Yes! The neon-bulb flashed. What can you say then about the flashing of the neon bulb and the shining of the torch bulb in a complete circuit?

☆☆☆

The 2 activities tell us one thing and that is that the energy particles responsible for the torch bulb shining and the neon-bulb flashing are the same. As you probably realise now these particles are the ELECTRONS. Therefore static electricity and current electricity are the same with exception that the electrons in static electricity are not moving as they do in current electricity.

HOW MUCH DO YOU KNOW?

Answer the following questions in your exercise books:-

1. Water molecules ..... across a ..... from a region of ..... to a region of ..... and we call this process .....
2. Osmosis is a special kind of .....
3. ..... and ..... enter root hairs of a plant by ..... and .....
4. ..... can be stored in one place while ..... is movement of energy particles.
5. A ..... is needed to make electricity ..... along ..... and this is provided by .....
6. ..... Force is produced when 2 surfaces are ..... against one another.
7. A negatively charged balloon will ..... and uncharged balloon but will ..... a ..... charged one.
8. A ..... charged balloon will repel a positively charged balloon but will ..... a ..... charged or an ..... balloon.
9. A small particle of electricity is the .....
10. An ..... is a ..... charged particle.

THE STRUCTURE OF THE ATOM

The idea that elements are made up of atoms is known as the Atomic Theory of Matter.

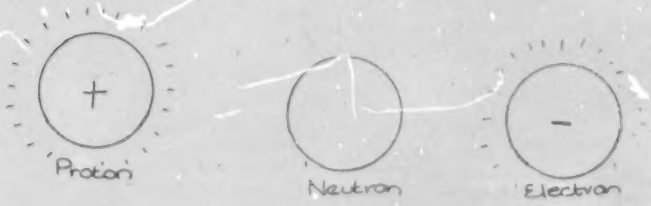
According to this theory, everything consists of atoms with empty spaces between them. These atoms although being the smallest particles of elements, are themselves built up from three energy particles.

☆☆☆ These particles are PROTONS, ELECTRONS AND NEUTRONS.

A Proton - is a particle with a positive charge.

An Electron - is a particle with a negative electric charge.

A Neutron - is a particle that has no electric charge therefore is neutral.



☆☆☆ 3 very important things about these particles are that:-

a) The negative charge on one electron is exactly equal (but opposite) to a positive charge of one proton.

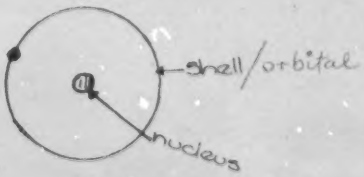
b) A proton and a neutron have the same mass.

c) The mass of an electron is very much smaller than either a proton or neutron so that its mass is negligible.

You will learn more about these particles later when we discuss how the atoms join together to make new substances.

Your teacher will show you a model of an atom.

An atom is round like a ball and has a centre which is called the nucleus of the atom. It has a shell which surrounds the nucleus.



To give you an idea of the relationship between the nucleus and the electron shell in terms of the space occupied by each in an atom, imagine a football field. The space occupied by the centre spot on the field would represent the nucleus of the atom and the rest of the playing field would be occupied by the electron shells forming what scientists call an electron cloud.

(Dont worry about the rectangular shape of the field, just think of the area the centre spot occupies in contrast with the rest of the playing field).

FOOTBALL FIELD

You can see from the above example that the nucleus occupies a very small space when compared with the size of the whole atom.

☆☆☆ Different kinds of atoms have different nuclei, therefore it is important to know something about the nucleus of an atom.

An atom has a mass. Most of the mass of the atom is contained in the nucleus.

We have already said that an atom is made up of 3 kinds of particles.
Do you remember what these are and what charges they carry

The shell of the atom is made up entirely of one kind of energy particle - the electron.

If the mass of the electron is negligible, what particles do you think make up the nucleus of the atom?

☆☆☆ The nucleus of the atom is made up of protons and neutrons in all cases except that of the hydrogen atom which has no neutrons.

If a charge on a proton particle is positive (+ve) and the neutron particle has no charge, the nucleus of an atom must be positively charged due to the presence of protons.

Since all matter is electrically neutral until charged (remember the experiments with balloons earlier in the unit) there must be a negative charge to neutralise the positive charge of the nucleus in the atom.

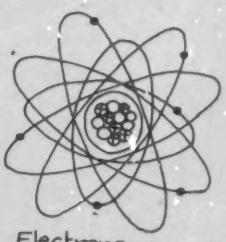
In the atom, what do you think is responsible for neutralising the positive charge of the nucleus?

☆☆☆

Every atom has (one in the case of hydrogen) electrons.

These electrons move very rapidly around the nucleus of the atom. As they do so they form a negatively charged shell which we call an electron shell. (Remember an electron carries a negative charge.)

However, the electrons around the nucleus of the atom do not move in one plane only, but move in all planes depending on the number of electrons in the atom i.e. size of the atom. Some of the electrons will move in a horizontal, vertical and oblique plane so that a negatively charged electron cloud is found surrounding the nucleus. The electrons present in the electron shells and the nucleus therefore comprise the atom.



Electrons moving round the nucleus of a Carbon atom

The number of electrons on an atom is equal to the number of protons, therefore the negative charges of the electrons balance the positive charges of the protons to give a neutral atom.

》《

We can summarise the structure of the atom as follows:-

a) It is the smallest particle of an element that can take part in a chemical change.

b) Has two parts - the nucleus which forms the centre and the electron shell(s) which surrounds the nucleus.

c) The electron shell(s) is (are) made up of electrons which move rapidly round the nucleus.

d) The nucleus consists of protons and neutrons.

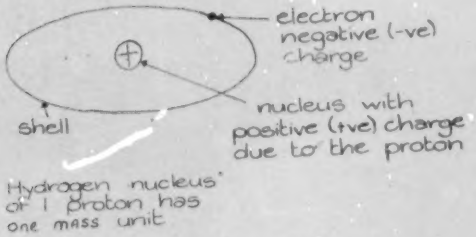
e) The nucleus carries a positive charge.

f) The shell(s) carry a negative charge.

g) The number of electrons in the shell(s) is equal to the number of protons in the nucleus.

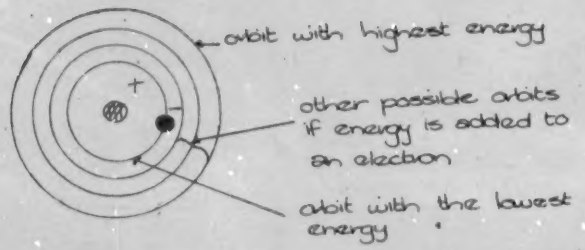
h) The atom is electrically neutral.

☆☆☆ If we examine an atom of hydrogen, we discover that it is the smallest and simplest of atoms.
It has one proton and no neutron in the nucleus.
It has one electron going round the nucleus thus forming one electron shell.



☆☆☆ The theory for the atomic structure of hydrogen whereby the sole electron travels in an orbit around a nucleus was put forward in 1913 by a Danish Scientist called Bohr.

We now refer to the Bohr's structure of a hydrogen atom with possible orbits or shells for the one electron to move in depending on whether the electron has more kinetic energy or not.



Bohr's structure for a hydrogen atom.

The one negative charge of the electron balances the positive charge of the one proton in the nucleus rendering the hydrogen atom neutral.

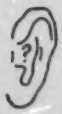
Why does the electron not leave its orbit? In other words what keeps the atom together?
In order to answer this question you need to remind yourself what you learnt earlier about magnets.

Remember the electron has a negative charge, and the proton has an exactly and equal positive charge.

So the two particles are held together in the same way that the opposite poles of a magnet are held together.

Therefore the electron does not easily escape from its orbit until acted on by another force e.g. gains or loses energy.

Let us now look at another element, this time a gas called helium. On examination, a helium atom is found to have 2 electrons in orbit around the nucleus.



If the negative charges of the 2 electrons are balanced by an equal number of positive charges in the nucleus, how many protons do you think are present in the nucleus of the helium atom?

Yes indeed, 2 electrons are balanced by 2 protons in the nucleus.

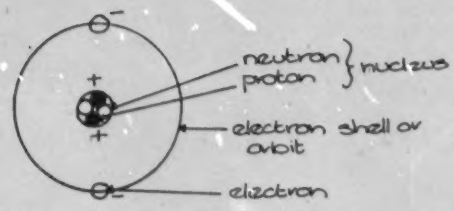
However, the mass of the nucleus of helium is 4 times as great as the mass of hydrogen nucleus.
Can you see an anomaly here?
Remember a hydrogen atom has 1 electron and 1 proton, but a helium atom has 2 electrons and 2 protons (mass of atom is concentrated in nucleus).

Since we have already said that the mass of helium nucleus is 4 times that of hydrogen, where does this extra mass of 2 come from?

☆☆☆ The mass of one proton is equal to the mass of 1 neutron therefore there must be extra particles in the nucleus.

These are the 2 neutrons. The mass of the 2 neutrons plus the mass of the 2 protons make the mass of the helium atom 4.

The structure of the helium atom consists of 2 electrons, 2 protons and 2 neutrons.



Helium Atom

TABLE 1

Atom	Electron shell (electrons)	Nucleus	
		Protons	Neutrons
Hydrogen	1	1	0
Helium	2	2	2
Lithium	3	3	3

Differences between Elements

There are 105 different elements known.
Are atoms of one element different from atoms of the other elements or are they the same? What do you think?

Atoms of different elements are different from each other, but atoms of the same element are the same.

☆☆☆

The difference lies in the electronic structure of atoms of each element. Hydrogen and helium though both gases are different because their atoms have different numbers of electrons, protons and neutrons.

However the number of electrons and protons in each atom of the same element is always the same. Scientists give this figure a special name - the Atomic Number.

The Atomic Number of an element then is the number of electrons or protons in each individual atom.

We will take a look at examples of other elements, those of oxygen, sulphur, manganese and copper.

If we examine the atoms of oxygen, we find that an atom of oxygen has 8 electrons in the shells and 8 protons in the nucleus.

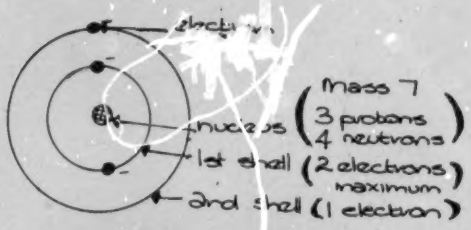
Therefore the atomic number of oxygen is 8. Similarly a sulphur atom has 16 electrons and 16 protons therefore its atomic number is 16.

Now do Exercise 3.

☆☆☆

ELECTRONIC CONFIGURATION

The electrons in an atom are arranged in layers called shells or orbits. These shells lie at different distances from the nucleus. The first shell can have a maximum of only 2 electrons in it. The lithium atom has three electrons so the first 2 electrons fill the first shell or orbit. The third electron occupies the second shell.
The arrangement of electrons around the nucleus of an atom is known as the ELECTRON CONFIGURATION.



LITHIUM ATOM

As the number of electrons increases, the number of shells also increases. The shells of an atom for easy reference are named K, L, M, N, and so on. The first shell is therefore referred to as the K shell and possesses a maximum of 2 electrons.

The second shell is the L shell and can have up to 8 electrons, the third shell M 18 electrons, the N shell 32 electrons.

One of the largest known atom is that of the element Lawrencium which has 103 electrons.

We have been discussing about electrons and protons.
What about neutrons? Where do they fit in?

As their name implies, neutrons are electrically neutral as we have already mentioned earlier.

They do not influence chemical properties of an element one way or the other, but, they do affect the mass of an atom.

Remember an atom of hydrogen has an atomic number of 1 (1 proton and 1 electron) has no neutrons and so its mass is 1.

However a helium atom with its atomic number of 3 has a mass of 7 therefore must have 4 neutrons.

When the mass of all the particles making up an atom are added, a figure is arrived at.

Scientists call this figure Atomic Weight or Atomic Mass of that element and is measured in atomic mass units.

The masses of a proton and a neutron are almost exactly one atomic mass unit.
Take the element Lawrencium which has an atomic number of 103.
Its atomic structure consists of 7 electron shells filled as follows:-

K	L	M	N	O	P	Q
2	8	18	32	32	9	2

The electron configuration of Lawrencium is 2/8/18/32/32/9/2.

☆☆☆ We can calculate the maximum number of electrons up to shell N by using this formula $2n^2$ where n is the shell or orbit number.

e.g. Maximum number of electrons in shell 1 is:-

$2n^2 = 2 \times 1^2 = 2$

Maximum number of electrons on third shell is:-

$2 \times 3^2 = 18$

Sodium atom has an atomic number of 11 therefore has 11 electrons and 11 protons.

Its atomic structure is as below:-

Sodium Atom

1st shell K = 2 electrons
2nd shell L = 8 electrons
3rd shell M = 1 electrons

Total = 11 electrons

☆☆☆ Electrons are negatively charged energy particles that move in shells around the nucleus of an atom.

VALENCY

☆☆☆ The outer most shell of any atom is referred to as the valency shell. Take as an example the atom of sodium which we looked at. The third and outer most shell or orbit is its valency shell.

How many electrons are there in the valency shell of a sodium atom? The maximum number of electrons that can be accomodated in the valency shell is 8.

An atom that has 8 electrons in its valency shell is referred to as having a STABLE OCTET. Such an atom is very stable and will not react with other metals easily, it is inert.

An example of such an element is the gas Argon or Neon. Both elements have 8 electrons in their outer most shells, the valency shells.

An atom can achieve a stable outer configuration by losing an electron or a number of electrons from the valency shell and leaving 8 electrons. An atom can also do this by gaining an electron from another atom to have a total of 8 electrons in its outermost shell.

The number of electrons gained or lost by an atom in order to achieve a stable octet gives the vallency number of that atom.

☆☆☆ When an atom gains or loses electrons in the valency shell that particle becomes a particle known as an ION and not an atom.

Depending on whether that atom has gained or lost an electron, it becomes a positive or negative ion.

Remember an atom is electrically neutral, so if it gains an electron, it becomes a negatively charged ion i.e. an ANION.

If the atom loses an electron it becomes a positively charged ion i.e. CATION, because the particle will be having one more +ve charge than negative charges.

Atoms normally gain or lose electrons when they join with other atoms in order to form new substances or compounds.

You shall learn more about elements joining to form new substances when we discuss about bond formation in the next part of the unit.

ISOTOPES

Some atoms of an element have the same number of protons and neutrons, but other atoms may have different numbers of neutrons in their nuclei. Since the mass number of an atom is the number of protons plus the number of neutrons present in the nucleus, an element may have atoms of different mass in its structure even though the atomic number of each atom remains the same.

☆☆☆ We call these atoms of an element that have different Atomic masses ISOTOPES.

The atoms that are isotopes have the same chemical properties as other atoms in a particular element because the number of electrons or protons remains the same for all atoms throughout that element.

Remember the neutrons have no influence on the chemical properties of an atom.

Examples of Isotopes

☆☆☆ Hydrogen has 3 isotopes and these are:-

1. Ordinary hydrogen atom of mass 1. i.e. 1 electron, 1 proton no neutron.

2. Deuterium - a hydrogen atom of mass 2, i.e. 1 electron, 1 proton, 1 neutron.

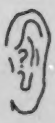
3. Tritium - a hydrogen atom of mass 3, i.e. 1 electron, 1 proton, 2 neutrons.

Oxygen has 2 isotopes and these are:-

a) Oxygen 16 with Atomic mass 16, i.e. 8 electrons, 8 protons and 8 neutrons.

b) Oxygen 18 with atomic mass 18, i.e. 8 electrons, 8 protons and 10 neutrons.

Therefore oxygen 18 has 2 extra neutrons in its nucleus, but the chemical properties of oxygen 16 and oxygen 18 are the same.



Your teacher will tell you more about isotopes of other elements and the usefulness of isotopes.

PERIODIC TABLE OF ELEMENTS

The world is full of elements all of which have different properties. Most are very rare and occur in small quantities. If we take all these elements and examine them physically and clinically, is there a pattern that emerges about them?

Scientists always try to classify things for easier identification and description. You did just that in Unit A2 when you classified the items in the basic kit. Some of you have visited a library at some stage. Think of the problems you would have in finding a book if they were haphazardly arranged and there was no classification. Could classification be extended to the elements as well? What do you think? Discuss this with your teacher.

During the last century scientists searched for patterns in the behaviour of elements.

In this unit we are going to examine a few elements and see how they are related to each other.

Do you remember in Unit F2 you classified some elements into metals and non-metals? Can you remember the characteristics you used for this classification?

ACTIVITY 3 Classification of elements.

Your teacher will provide you with the copper, magnesium, iodine, sulphur, calcium, iron and lead elements which you have to examine. Use the characteristics you used before to distinguish metals and non-metals and decide in which group the elements your teacher has given you fall.

Your classification of the above elements should show that copper, magnesium, calcium, iron and lead are all metals, and the rest are non-metals.

Now, could the metals be classified further?

In order to answer that question, carry out the experiment below.

EXPERIMENT 8 : Reaction of metals and water.

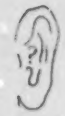
You will need

calcium metal
magnesium metal
copper metal
lead metal
water
small plastic bottle
universal indicator paper

Place calcium metal (5 grams) into a small plastic bottle and add 5 ml of water. After 5 minutes dip into the plastic bottle a strip of universal indicator paper.

Note the reaction.

Clean out your small plastic bottle and repeat the above with copper metal, lead metal, iron and magnesium.



Take note of your observations each time.

When you have reacted all the metals above, discuss the results with your teacher and proceed to carry out the experiment below.

EXPERIMENT 5 : Reaction of metals with dilute acid.

You will need:

The same metals as you used in Experiment 1.
10 ml acetic acid
plastic bottle
matches

Pour 2ml of acid into the plastic bottle. Drop 2 small lumps of calcium into the bottle. Place a finger on the bottle-top to stop gas escaping. After about 1 minute light a match stick and bring the flame near the closed mouth of the bottle. Now remove your finger. Write down your observations. Rinse the bottle out and repeat the procedure with the rest of the metals.

Write your observation down for each metal.

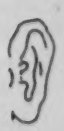
From the experiment you carried out in Unit F2 you learnt that a dilute acid can react with a metal to produce a gas hydrogen which, when lighted, pops.

In this experiment which metals reacted with the acid to produce hydrogen?

From the 2 experiments it should be clear to you that there are some differences in chemical behaviour among metals, therefore it is possible to separate metals into groups.

In the first experiment, magnesium and calcium both reacted with water to produce a solution which, when tested by universal indicator, was found to be basic. Copper and lead did not react with water and the universal indicator never changed colour.

Similarly, magnesium and calcium reacted with dilute acid to produce hydrogen gas while lead and copper did not. We can therefore say magnesium and calcium metals belong to the same group and copper and lead belong to another group.



If we can separate metals into different groups, can we do the same with non-metals? What do you think? Discuss this with your teacher and carry out the experiment below.

EXPERIMENT 10 Heating sulphur, carbon and iodine

You will need:

iodine
sulphur
match sticks
universal indicator paper
spatula
burner
evaporating dish
stand
jam jar

Gently heat a small amount (about half a spatula) of sulphur in an evaporating dish. Place a piece of universal indicator paper in a jam jar. Wet it to make it stick and to absorb the fumes.

As the smoky gas (fumes) come off the sulphur, place the jam jar over the burning sulphur. Observe what happens to the universal indicator paper. Scrape the evaporating dish clean and repeat the same procedure, this time with pieces of match sticks and also with one small crystal of iodine. (N.B: DO NOT BREATHE IODINE FUMES) (heat the sulphur and iodine for a very short time, say half a minute and stop as soon as you see fumes coming off).

Each time observe the reaction of the wet universal indicator paper

In the above experiment, fumes are produced when all the three non-metals are heated. Did the gases produced when the substances were heated have the same colour?

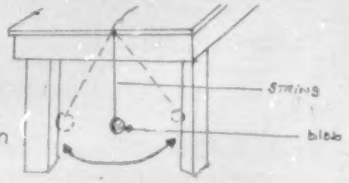
With sulphur and carbon, the fumes produced on heating were acid, but the fumes from iodine remained neutral. From this observation sulphur, carbon and iodine, though all non-metals could be separated into two groups on the basis of this chemical property.

Further separation between carbon and sulphur can be done on the basis that sulphur melted at low temperature, while carbon did not.

☆☆☆ Iodine when heated produced purple fumes which remained neutral, therefore it belongs to a different class of non-metals, called Halogens, which have special physical and chemical properties. We will discuss the properties of Halogens later.

☆☆☆ All known elements are now systematically listed on a chart. How was this chart compiled? In the middle of last century a Russian scientist by the name of Mendeleev produced an early form of this chart. On it he arranged the elements which he had discovered in order of increasing atomic mass. Along the series, he found repetition, or patterns, in the properties of the elements and their compounds that he had discovered, and predicted that those elements still to be discovered would follow this pattern.

This repeating sequence in properties is called Periodicity. Watch the pendulum which your teacher has set up, as it swings backwards and forward.



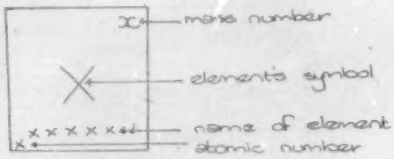
a swinging pendulum

The movement of the blob is periodic since it traces out a repeating pattern with time.

The patterns of properties of elements on the chart are periodic because they show repeating time with atomic number. This list of elements has subsequently come to be known as the Periodic Table of elements.

Look at the Periodic Table on page 37.

As you can see, on it are symbols of elements in boxes as well as figures.



The Periodic Table may not look much like classification but among all these symbols and figures are different sets or classes of elements. The Periodic Table can act as a skeleton upon which you can build your chemical knowledge. To chemists it is of great importance, as it is vital to the study of properties and reactions of millions of known substances and in the attempts to make new ones.

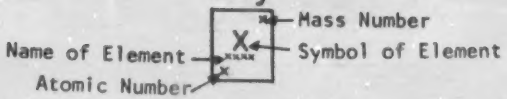
The Table can be looked on as having two sections to it. On the left hand side are non metals and on the right hand are metals. The two are divided on the chart by a thick black line which forms a zigzag pattern in the form of steps like this → Can you find it on your chart ?

At the top of the Periodic Table are figures in Roman numerals. What number do they go to? These numbers represent the list or columns of elements going down the chart. The columns are also referred to as groups.

☆☆☆ Horizontally are rows of elements. These rows make the periods of elements. Look at the Periodic Table again, leaving out the bottom two rows entitled Lanthanide Series and Actinide Series. How many groups (columns) and periods of elements make up the Periodic Table?

Yes, the elements are divided into 8 groups and 7 periods.

PERIODIC TABLE OF ELEMENTS



I	II	III	IV	V	VI	VII	VIII (Inert (Noble) Gases)
							2 He Helium 4
1 H Hydrogen 1							
3 Li Lithium	4 Be Beryllium	5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon 20
11 Na Sodium 23	12 Mg Magnesium 24	13 Al Aluminium 27	14 Si Silicon 28	15 P Phosphorus 31	16 S Sulphur 32	17 Cl Chlorine 35.5	18 Ar Argon 40
19 K Potassium 39	20 Ca Calcium 40	31 Ga Gallium 70	32 Ge Germanium 73	33 As Arsenic 75	34 Se Selenium 79	35 Br Bromine 80	36 Kr Krypton 84
37 Rb Rubidium 85.5	38 Sr Strontium 88	49 In Indium 115	50 Sn Tin 119	51 Sb Antimony 122	52 Te Tellurium 128	53 I Iodine 127	54 Xe Xenon 131
55 Cs Caesium 133	56 Ba Barium 137	81 Tl Thallium 204	82 Pb Lead 207	83 Bi Bismuth 209	84 Po Polonium 210	85 At Astatine 210	86 Rn Radon 222
87 Fr Francium 223	88 Ra Radium 226						

Alkali Metals

Alkali Earth Metals

Halogens

Transitional Elements

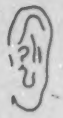
21 Sc Scandium 45	22 Ti Titanium 48	23 V Vanadium 51	24 Cr Chromium 52	25 Mn Manganese 55	26 Fe Iron 56	27 Co Cobalt 59	28 Ni Nickel 59	29 Cu Copper 64	30 Zn Zinc 65
39 Y Yttrium 89	40 Zr Zirconium 91	41 Nb Niobium 93	42 Mo Molybdenum 96	43 Tc Technetium 99	44 Ru Ruthenium 101	45 Rh Rhodium 103	46 Pd Palladium 106	47 Ag Silver 108	48 Cd Cadmium 112
57 La Lanthanum 139	72 Hf Hafnium 178.5	73 Ta Tantalum 181	74 W Tungsten 184	75 Re Rhenium 186	76 Os Osmium 190	77 Ir Iridium 192	78 Pt Platinum 195	79 Au Gold 197	80 Hg Mercury 201
89 Ac Actinium 227									

Lanthanide Series	57 La Lanthanum 139	58 Ce Cerium 140	59 Pr Praseodymium 141	60 Nd Neodymium 144	61 Pm Promethium 147	62 Sm Samarium 150	63 Eu Europium 152	64 Gd Gadolinium 157	65 Tb Terbium 159	66 Dy Dysprosium 162.5	67 Ho Holmium 165	68 Er Erbium 167	69 Tm Thulium 169	70 Yb Ytterbium 173	71 Lu Lutetium 175
Actinide Series	89 Ac Actinium 227	90 Th Thorium 232	91 Pa Protactinium 231	92 U Uranium 238	93 Np Neptunium 237	94 Pu Plutonium 242	95 Am Americium 243	96 Cm Curium 247	97 Bk Berkelium 247	98 Cf Californium 251	99 Es Einsteinium 254	100 Fm Fermium 253	101 Md Mendelevium 256	102 No Nobelium 254	103 Lr Lawrencium 257

What happens to the atomic numbers and atomic mass numbers of the elements as you go down groups and across periods? You have done some experiments with a number of elements before. Can you see the elements on the chart and to what group they belong? In which groups do these elements, Magnesium, calcium, oxygen, sulphur, copper and silver belong?

When you placed calcium and magnesium metals in water a gas was evolved which, when tested with a burning splinter 'pops'. Do you remember what gas this was and from the table in what group it belongs?

☆☆☆ Hydrogen, though a gas, behaves sometimes like a metal and so can combine with non metals. It is replaced in water by elements of Group I and Group II which are collectively termed Alkaline and Alkaline Earth metals respectively.



Your teacher will now tell you more about these elements of Group I and Group II.

Take a look again at Periodic Table. In what group does iodine belong?

Tell the class what the elements are in this group.

The elements of group VII are collectively known as Halogens. (Halogen means salt-former).

They show a marked general similarity of properties.

The Halogens form yellow to brown or purple coloured gases with unpleasant smells. You have already seen the iodine gas. What colour is it?

How do these elements of group VII react?

To answer that question you have to carry out the experiment below.

EXPERIMENT 11 Reacting magnesium with iodine.

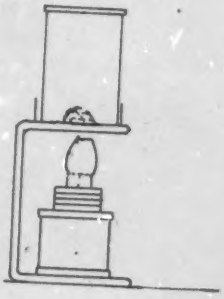
You will need:

iodine crystals
magnesium metal
aluminium paper foil
burner
stand
evaporating dish
boiling tin

Take a strip of magnesium ribbon 3cm long. Scrape it with a sharp object until it is very shiny. Make a ring out of the magnesium. Place this magnesium ring on to a piece of aluminium foil and also one crystal of iodine.

Fold the aluminium foil to make a secure parcel containing magnesium ring and an iodine crystal.

Place the parcel in an evaporating dish and over the parcel place a boiling tin to prevent excessive fumes filling the classroom. Gently heat the evaporating dish for a very short time, say half a minute. Stop heating the iodine as soon as you see the iodine gas (fumes) coming off.



Allow to cool before opening the parcel.

What colour is the magnesium ring now?
Scrape it to look at the new substance formed.

Halogens react readily with elements in Group I and Group II to form salts

☆☆☆

e.g.: sodium + chlorine ⟶ sodium chloride (common salt)

magnesium + iodine ⟶ magnesium iodide (salt)

Looking at your Periodic Table, can you think of other salts that can be formed with alkaline metals and halogens?

Hydrogen, a gas, is in Group I. Do halogens react with it as they do with other elements in Group I and II.

To find out, carry out the experiment below.

EXPERIMENT 12 Reacting hydrogen with iodine.

You will need:

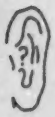
iodine crystals
evaporating dish
universal indicator paper
acetic acid
magnesium ribbon
stand
burner
jam jar.

Place one crystal of iodine into an evaporating dish and place this on a stand. Place three 1cm pieces of magnesium into a plastic bottle with 5ml acetic acid.

Over this plastic bottle place a jam jar with a wet universal indicator paper in it. Let the reaction continue for about 5 minutes in the plastic bottle so that the jar fills with hydrogen gas.

Carefully remove the jam jar now full of hydrogen gas and place it over the evaporating dish (with an iodine crystal) on the stand.

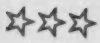
Gently heat the iodine crystal until you see purple fumes coming off the crystal. Remove the heat as the jar fills with purple fumes. Observe the wet universal indicator paper in the jam jar.



Discuss the results with your teacher.

Chemically, Halogens react readily with hydrogen to form acids. In the experiment above, iodine gas joined chemically with hydrogen gas in the jar to form an acid called hydrogen iodide which caused the yellow wet indicator paper to turn reddish.

Iodine gas + Hydrogen gas ⟶ Hydrogen Iodide (an acid)



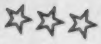
Other Halogens, like Chlorine and Fluorine react even more readily with hydrogen than Iodine gas.

Chlorine gas + Hydrogen gas ⟶ Hydrogen Chloride (Hydrochloric acid)

If you now take another look at your Periodic Table you will see there, a large section of elements situated between Group II and Group III.

What is the first and last element in this group?

Tell the teacher any other elements you have already met that are in this group. These elements from Scandium to Gemanium and those below them are all metals called "heavy" metals or Transitional Elements. They are "heavy" because they have high densities. Some of the metals in this group are very rare indeed. These transitional elements (transitional because they are in the middle since they may behave either as metals or non metals) are of special interest to scientists and are used a lot in industry. They have very interesting properties. Some are very reactive metals, e.g. Titanium, while others are non reactive, e.g. gold. Gold is a very valuable metal because of this chemical property that it does not react with any other element under normal conditions.



Now do the activity below.

ACTIVITY 4 To examine solutions of compounds made from transitional elements.

Your teacher is going to show you some chemicals made from transitional elements.

Examine these and copy and fill in, in your text books, a copy of the table your teacher will put on the board. Then discuss this with your teacher.

Most transitional elements are used in industry as Catalysts. These are substances that help to quicken or slow down chemical reactions without they themselves changing at the end of the reaction. Good examples of these catalysts are vanadium, nickel, manganese and palladium.

You have used the metal copper a lot in experiments. Remember Unit 1 on electricity? Copper, together with other transitional elements, is used a lot in the electrical and electronics world because they are good conductors of electricity as well as of heat.

Take a look at the Periodic Table chart your teacher has put on the wall. This chart shows the complete electron configuration of each element.

What do you notice about the electron configuration of elements in Group VIII? There is something common about these elements of Group VIII. What is it? Tell your teacher.

☆☆☆ All objects of Group VIII constitute gases. These are the INERT or NOBLE gases. They are said to be inert because they do not react with any other element except under extreme conditions of high pressures and high temperatures.

Zenon hexafluoride is a stable compound formed between the reaction of zenon, a noble gas, and fluorine, a halogen, under very high temperatures. The elements of Group VIII are inactive because of their electron structure. All have 8 electrons in outer shells, thus are known as a stable octet.

☆☆☆ Where a stable octet exists, it means that the shell of the atom is satisfied and stable, therefore the atom will not readily lose or accept other electrons. This causes the elements of Group VIII to be very stable indeed and inert.

E.Q.

Answer the following questions from past AEB examinations.

1.

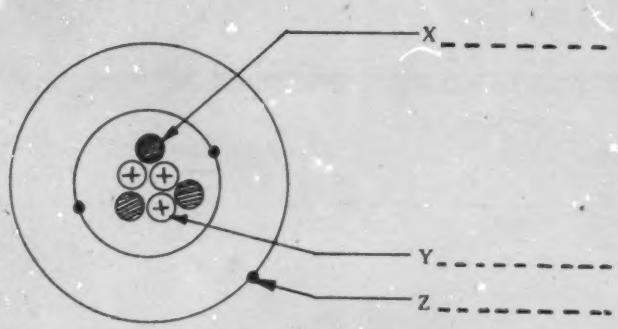


Fig. 1

(a) In the representation of a simple atom, Fig 1, state the identity of the three particles X, Y and Z.

X .....Y .....Z .....

(b) The atom above can lose a negatively charged particle to form a positively charged ion. State one condition under which this loss may occur.

.....

2. An isotope of sodium has an atomic number of 11 and a mass number of 23.

(a) How many (i) neutrons are there in one atom of this isotope? .....

(ii) electrons are possessed by one neutral atom of this isotope? .....

(b) How does a neutral atom of this element differ from the particles of sodium in sodium chloride?

.....

(c) Complete Fig 2 to show the structure of a neutral sodium atom.

	1st shell	2nd shell	3rd shell
Number of electrons in			

Fig 2 (5 marks)

(c) Describe the structure of an atom.

.....

3.

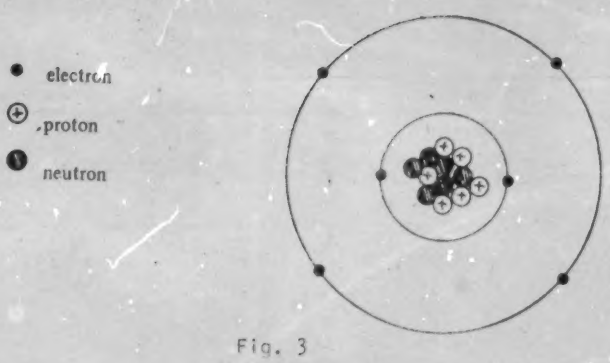


Fig. 3

Fig. 3 represents an atom of an element

(a), How do you know that this represents an atom rather than an ion?

.....

(b) How would the diagram of an atom of another isotope of this element differ from the diagram above?

.....

(c) What would be the effect of changing the number of protons in the nucleus.

.....

4.

Fig.4, refers to the structure of an atom of an element with eleven protons in the nucleus.

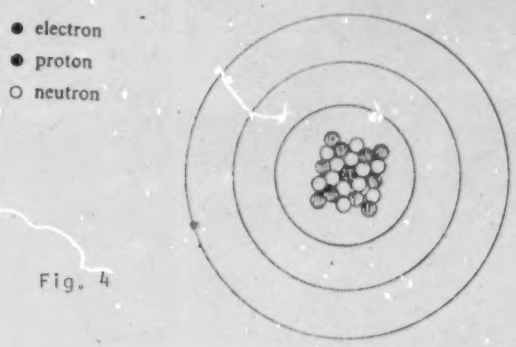


Fig. 4

(a) Complete the diagram to show the number of electrons in the first and second shells.

(b) Does the completed diagram represent the atom of a metal ; or non-metal? Give the reason for your answer.

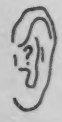
.....

.....

RADIO-ACTIVITY

Take a look at your Periodic Table.

Going down the elements in Group 5 you will come across an element called Bismuth.
What is its atomic number?
How many protons does it have in its nucleus?



Scientists have discovered that all elements that have their nucleus more complex than that of the nucleus of the bismuth atom i.e. containing more than 83 protons are unstable.
Can you name a few of the atoms whose nuclei are more complex than that of Bismuth?

'Good' - This means that the nuclei of these atoms may disintergrate or break down and split on their own.
This splitting of the nucleus of an atom leads to what is known as Radio-activity.

DEFINITION.

☆☆☆ Radio-activity is the spontaneous splitting up of the atoms containing complex nuclei of certain elements resulting in the emission of other very small particles.

Radio-activity can be detacted by a device known as a Geiger - Muller counter.
The instrument consists of a tube and a counter and it detects the presence of the emitted particles and their intensity.
The rate at which radio-activity occurs does not depend on temperature or any other physical or chemical factor and it is not a chemical change.

☆☆☆ When the nucleus of an atom like radium splits, there are three kinds of particles that are released.
These particles are:-

a) Alpha particles (from Greek Alphabet α)

b) Beta particles (" " " β)

c) Gamma rays (" " " γ)

Two of the above particles i.e. Alpha and Beta have different electric charges.
They can be deflected by a magnetic field.

The gamma rays have no charge.
We will now look at each particle more closely.

☆☆☆ 1 ALPHA PARTICLE (α Particle)

An alpha particle is a positively charged particle that moves at very high speed.
It has been identified as a helium atom minus 2 electrons that is a helium ion He^{++}
Remember a helium atom has 2 neutrons in its nucleus.
The particle is precisely just the nucleus of the helium atom.

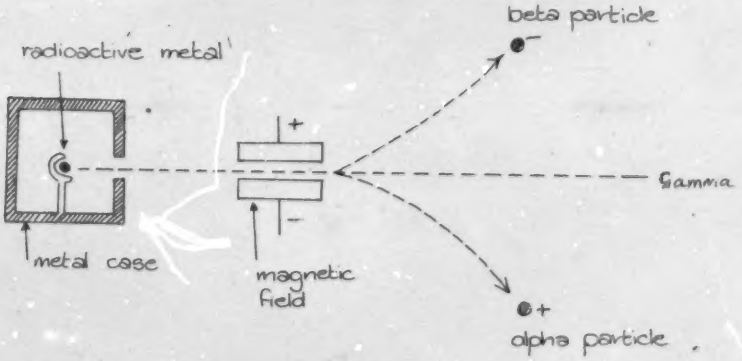
☆☆☆ 2 BETA PARTICLE (β -particle)

A Beta particle is a negatively charged particle of very little mass. It has been identified as an electron that also moves at very high speed.

☆☆☆ 3 GAMMA RAYS (γ -rays)

These are not particles in the true sense of the word, but are electro-magnetic waves similar to light.
They have a frequency of 1 000 000 higher than light, therefore are different from light.
The gamma rays can penetrate solid objects like brick walls, wood and thin metal easily.
When the rays are passed through a magnetic field, they are not deflected therefore gamma rays have no charge.

See diagram below:



When the nuclei of radium, uranium, plutonium and other radio-active atoms disintergrate a great amount of energy is released. Under controlled conditions the energy released can be harnessed and used as nuclear power to suppliment our energy requirements.

☆☆☆

Half- Life.

The nucleus of radio-active elements disintergrate or decay at a certain rate.
Scientists express the degree of stability of a radio-active element in terms of its half - life.

ACTIVITY 5 Making a model of half-life of an element.

A model showing the half-life of an element can be made with a bag of 5g masses which represent the atoms of an unstable decaying radio-active element.

Your teacher will provide you with a 5g mass.

At a given time spin or throw your mass into the air.

Let it settle down and take note of the side that is uppermost (facing upwards). (The 5g mass has two sides: one marked 5g and the other side is plain).

The teacher will count how many of you have a plain side and how many had the side marked 5g uppermost. Your teacher will explain to you how to continue with the model.

Each time you threw the masses about half of those thrown were "decayed" and changed, the rest were unchanged and remained the same element. If a graph is plotted of your results, it will show how an unstable radio-active element decays over a period of time. This is called half-life.

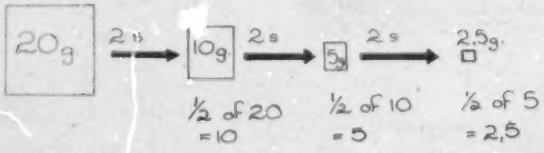
☆☆☆

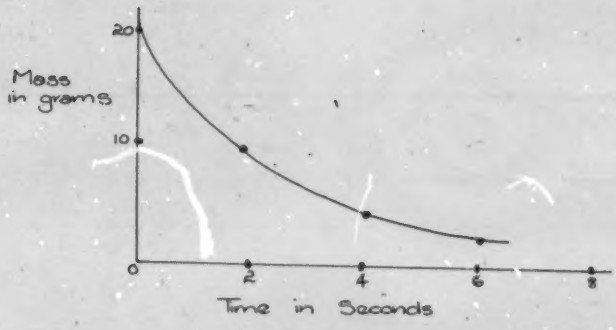
DEFINITION

The half - life of an element is the time required for its radio-activity to fall by half from its observed value at any given moment.

This half- life may vary from a fraction of a second for very unstable elements to millions of years for others.
Take the following as an example:-

If a radio-active element has a half-life of 2 seconds, then a 20 gram piece of that element would decay to 10 grams in the 1st 2 seconds then to 5 grams in the second 2 seconds then 2.5 grams in the 3rd 2 seconds period.





☆☆☆ Therefore 20 grams will decay from 20 grams to 2.5 grams in 6 seconds.
Other examples of half - life are given below:-

Radium has a half - life of 1620 years.
Thorium has a half - life of 24 days.
Protactinium has a half - life of 1.6×10^{-4} seconds.

Uses of Radio-Activity and Radio-Isotopes

☆☆☆ Radio-activity and radio-isotopes have many important uses that benefit man.

Some of these uses are:-

1 In Medicine

Some diseases like cancer may be destroyed by exposure to gamma - rays which are derived from the decay of radio-active materials.

Radio-isotopes e.g. those of barium can be used in diagnosis of diseases as tracers.

2 In Archeology

Radio-active carbon plays a part in dating of archeological specimens.
This is known as carbon dating.
The half - life of radio-active carbon is 5760 years.
Radio activity of ancient samples of wood can easily be determined and so the age of the samples.

3 Industrial Use

Water pipe mains can be tested for leaks by using radio-isotopes.
Radio-activity is also used to provide energy through nuclear power stations.
For many years radio-active elements like uranium and Plutonium were used to manufacture nuclear weapons of war e.g. nuclear bombs and nuclear war heads.

Dangers of Radioactive Material to Health.

Radio-active materials are very dangerous to health.
The danger is that very small exposure toradio-activity will lead to serious illness and severe exposure will cause death.
A person may not necessarily be aware that he is exposed to radiation.
Diseases of the blood like Leukaemia or cancer will result.
This means that radio-active material need to be handled with great care.
They should not be handled by anyone without an adequate protection from the radiation.

Now do Exercise 4.

PART 4.

BONDING

When elements join together they form a compound.
The chemical union that takes place between 2 or more elements is called Chemical Bonding.

You remember very well the differences between elements and compounds to realise that the characteristics of compounds are far removed from the characteristics of the elements from which they are made. This means that something will have happened to the elements when they form the compound.

When you studied the Periodic Table of elements you learnt that the elements of Group VIII were very stable, or inert.

Why were these elements stable? To remind you again, here is the electronic configuration of those elements:

Helium 2 (duplet)
Neon 2, 8.
Argon 2, 8, 8.
Krypton 2, 8, 18, 8.
Xenon 2 ..... 8.
Radon 2 ..... 8.

All other elements are unstable, therefore react because they do not possess an electronic configuration that ends like that of Helium (2) or with 8 electrons in their outermost shell.
They will react, therefore, in order to achieve a stable octet structure.

How do these reactive elements achieve this stable octet configuration?

Think of an atom that has more than 8 electrons in its outermost shell and another atom with less than 8 electrons, also in its outermost shell, or 2 atoms, both with less than 8 electrons in their outer shells. What would have to happen to these atoms so that all end up with 8 electrons in their outermost shells.

Think hard!

Obviously, the atom with 9 electrons in the outer shell will have to lose one electron in order to leave 8 and the one with 7 electrons will have to gain one from somewhere in order to achieve a stable octet. If both atoms have 7 electrons each in their valency shells, then they both have to gain an electron each, or both have to come together and mutually share electrons.

We will now see how this happens. There are many ways by which elements can join to form compounds. In this unit you will learn two of these:

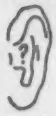
☆☆☆

1: Electrovalent or Ionic Bonding
2: Covalent Bonding

Electrovalent or Ionic Bonding

☆☆☆ This is the chemical combination that takes place between elements on the left hand side of the Periodic Table, the metals, and those elements onthe right hand side, the non-metals.

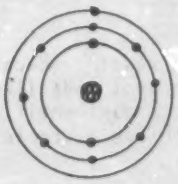
In electrovalent bonding there is the transfer of one or more electrons from one atom, usually a metal to another atom a non-metal.



This kind of thing happened when you formed that black mass which would not be attracted by a magnet in Unit C1.
Do you remember what you called that black mass?

In that experiment from C1, the metal iron combined chemically with a non-metal sulphur to form a new compound IRON SULPHIDE.

Now let us look at the electron structure of the two elements of sodium and chlorine that join chemically together to form common salt.



Sodium Atom
2,8,1

Chlorine Atom
2,8,7

☆☆☆ Sodium is a metal. On the Periodic Table it is found in the first group of elements.

The structure of a sodium atom shows that it has 11 electrons, 1 in its valency shell and so has a valency of one.

On the other hand chlorine is a non-metal. It is in fact a yellow gas with a choking smell. It lies in Group 7 of the Periodic Table and electronically chlorine has 17 electrons, 2 in the K shell, 8 in the L shell and 7 in its M or valency shell.

Sodium will need to lose one electron and chlorine will need to gain one electron in order for both atoms to achieve a stable octet configuration.

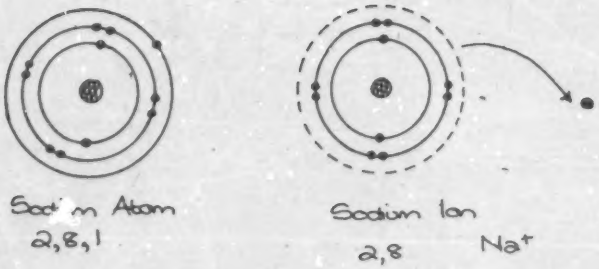
For sodium the new configuration would be 2, 8 while for chlorine the new configuration would be 2, 8, 8.

This happens when the 2 atoms combine chemically.

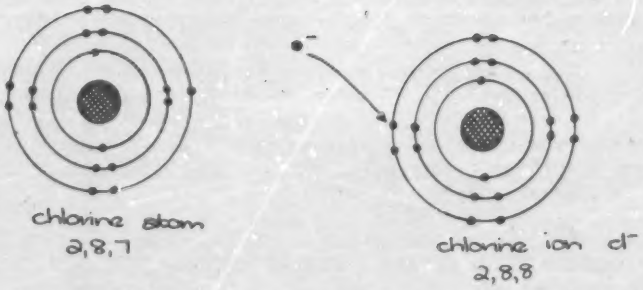
Before an atom combines with another, it has to form a particle known as an <u>ION.</u>

We have already said something about ions in this unit. Do you remember what we called a positive ion and what we called a negative ion?

☆☆☆ In order for an atom to form a stable octet it has to gain or lose an electron(s).



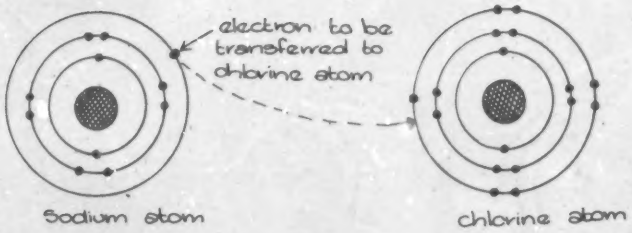
The sodium atom has lost an electron to form sodium ion Na^+.

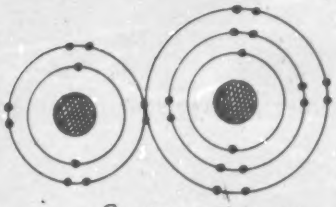


The chlorine atom has gained an electron to form a chlorine ion Cl^-

☆☆☆ A chemical bond is formed between the atoms of sodium and that of chlorine when the valency electron has been transferred from the sodium to the chlorine atom.

Such a bond is known as an electrovalent bond.





Atoms cannot lose electrons easily because this involves pulling a negative particle (the electron) away from the attraction of the positive nucleus.
To remove one electron from an atom requires a considerable amount of energy.

For an atom to lose two electrons, a large amount of energy is required and the loss of three electrons involves a great deal of energy. It is, therefore, not surprising that atoms with a large number of electrons on the outer shell do not lose all these electrons to other atoms. The effort would be far too great!

☆☆☆ Metals like sodium, magnesium, and aluminium lose 1, 2 and 3 electrons respectively and form cations with 1, 2 and 3 charges respectively, each with an electron structure showing an octet configuration. Similarly the non-metals in group 5, 6 and 7 - Nitrogen, Oxygen and Fluorine will accept 3, 2 and 1 electron respectively to form Anions simillar in structure to some of the inert gases. Only electrons in the valency shell are involved or take part in electrovalent bonding.

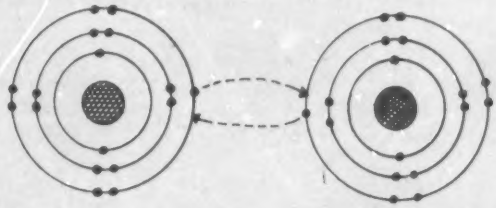
☆☆☆ COVALENT BONDING

In this type of chemical combination, electrons are neither lost nor gained by the atoms that are forming a chemical bond.

Instead there is a sharing of electrons between the joining atoms. Each atom provides an electron(s) to be shared equally.

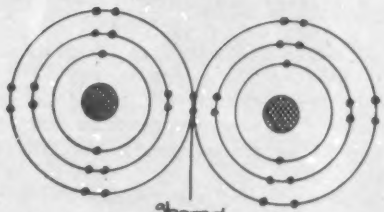
Covalent bonding takes place between the atoms listed on the right hand of the Periodic Table. These are the non-metals.

If we consider two chlorine atoms joined together to form a molecule of chlorine gas Cl:Cl (Cl_2) , we see that the electron structure of each atom is like this:-



chlorine atom
2,8,7

chlorine atom
2,8,7



chlorine molecule
(Cl_2)

When atoms join covalently they form molecules which possess low melting and boiling points.
Substances such as pure water, concentrated acids and all organic substances like alcohol or petrol contain covalent bonds.

What characteristics do these substances, formed by electrovalent and covalent bonding, possess? In order to answer that question, carry out the following experiment.

EXPERIMENT 13(a) Conduction of electricity through a solid.

You will need:

	battery box
	conductor wires
crystals of copper sulphate	torch bulb
sodium chloride	water
sugar	evaporating dish
naphthalene flakes	spatula.
calcium chloride	plastic cup

Connect your battery box with your wire conductors to the torch bulb so that when you have a complete circuit you get the bulb shining.

Take some crystals of sodium chloride (2ml measure). Place the crystals in a plastic cup ; touch 2 conductor ends of the wire on to the crystals of sodium chloride to make a complete curcuit with the bulb, and the battery box.

Observe what happens to the bulb. Empty the sodium chloride from the plastic cup and repeat the same procedure, this time with sugar, naphthalene flakes and calcium chloride. Observe the bulb each time.

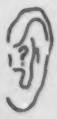
EXPERIMENT 13(b) Conditions of electricity through a molten substance.

Now gently heat 5ml measure of sodium chloride to melting point in an evaporating dish and connect up the wires to the bulb and complete the circuit by dipping the two ends of the conductor wires into the molten salt. Observe what happens to the torch bulb. Make sure the ends of the wires do not touch the bottom or sides of the evaporating dish. Why?
Scrape all salt off the evaporating dish, and repeat the above procedure with the 3 remaining substances, naphthalene flakes, sugar and calcium chloride. Observe what happens to the bulb each time.

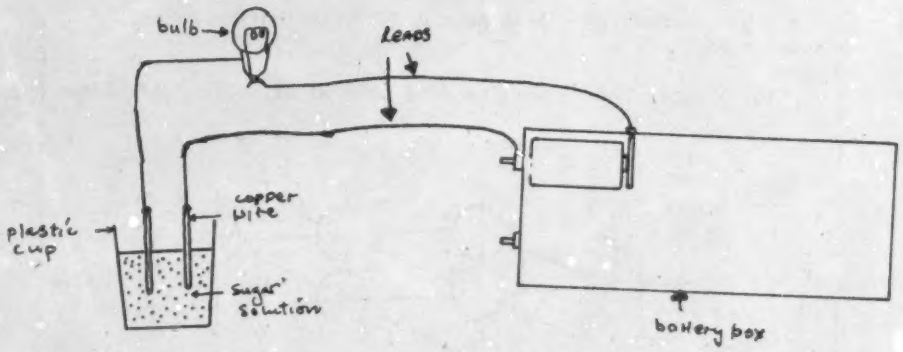
EXPERIMENT 13(c) Conduction of electricity through a solution.

Clean the plastic cup again and place 30ml of water into the plastic cup Dissolve 5ml measure of sodium chloride. Stir well. Connect up the wires as before and dip the two wire conductor ends into the salt solution.
Repeat the above with sugar solution.
Observe what happens to the bulb again.

Copy the table the teacher will put on the board and fill in your results from the 3 last experiments.



Discuss your results with the teacher and write your conclusions in your exercise books.



From your results of the last 3 experiments it is clear that the compounds formed by electrovalent bonding have different characteristics to those that are formed by covalent bonding.

We can summarize these in the following way:

SUMMARY OF TYPES OF BONDS

Electrovalent	Covalent
e.g. Sodium chloride calcium chloride copper sulphate	e.g. Naphthalene chlorine gas sugar Hydrogen Chloride gas
Electron(s) transferred completely	Electrons equally shared
Strong bonds to all ions of the opposite charge	Strong bonds inside molecules but little attraction between molecules
No separate molecules formed	Separate molecules formed
Substances formed, may dissolve in water	Substances formed, not readily dissolve in water.
Conduct electricity in molten or dissolved state but not in solid state	Do not conduct electricity at all whether in solid, molten or solution state

Now do Exercise 5.

E.Q.

Here are more questions from past A.E.B. examination papers. Answer them.

1. Fig. 1 represents a portion of a crystal of sodium chloride.

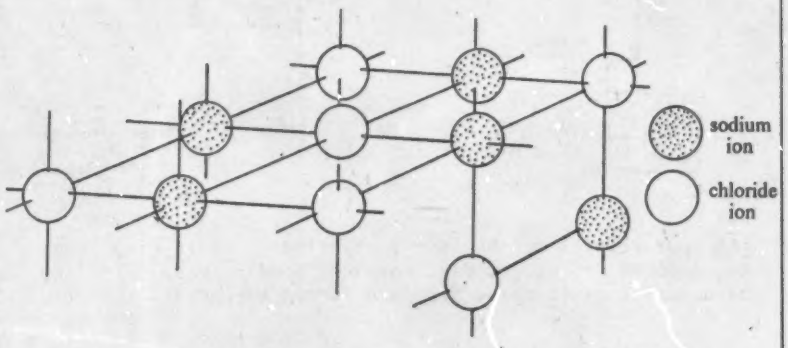


Fig. 1

(a) State one way in which the rigid bonds between the sodium ions and chloride ions could be broken.

.....

(b) Explain why such rigid bonds exist between the sodium ions and chloride ions.

.....

.....

(c) Name one process -

(i) whereby sodium ions can be converted to sodium atoms,

.....

(ii) whereby sodium atoms can be converted to sodium ions.

.....

2. The element uranium, slowly changes to lead.

(a) What is the name given to the process which causes this change?

.....

(b) Name and describe one particle emitted during this change.

.....

.....

(c) Name one device that could be used to detect when such changes are taking place.

.....

3. In the upper atmosphere neutrons from cosmic rays bombard nitrogen atoms to form a radioactive isotope of carbon together with hydrogen atoms.

(a) Explain the meaning of the underlined words.

.....

.....

.....

(b) Suggest one use that could be made of a raioactive isotope such as that of carbon.

.....

(c) Suggest how you could detect the presence of a radioactive isotope.

.....

4. A radioactive isotope X spontaneously changes to a stable isotope Y.

(a) What is the name given to such a change? .....

(b) State one way in which you could detect that such a change is taking place.

.....

(c) Explain one practical application of such a change.

.....

5. Fig. 2. represents the structure of six particles, the shaded areas representing the nucleus of each particle.

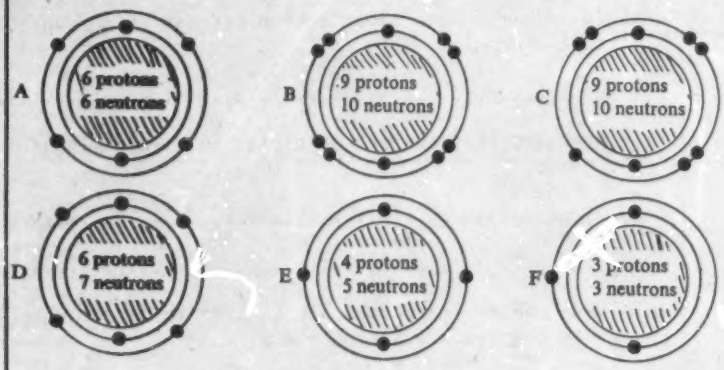


Fig. 2

● = electron

Which of the particles represented in Fig. 2,

(a) will move towards the anode during electrolysis?

.....

(b) are isotopes of the same element? .....

(c) is most likely to combine with F? .....

(d) State two products that might be obtained when one of the larger neclei is split.

.....

6. "When plants and animals die, renewal of the radiocarbon ceases and the carbon 14 decays at a known rate, the half-life being 5568 years. We can find the age of a specimen by measuring the radioactivity of the remaining carbon 14."

(a) Explain the meaning of the term "half-life". Would an element with a half-life similar to that of carbon be a suitable element to use as a radioactive tracer in medicine? Give the reason for your answer.

(b) Fig. 3. shows the decline in intensity of radiation with time for an element X.

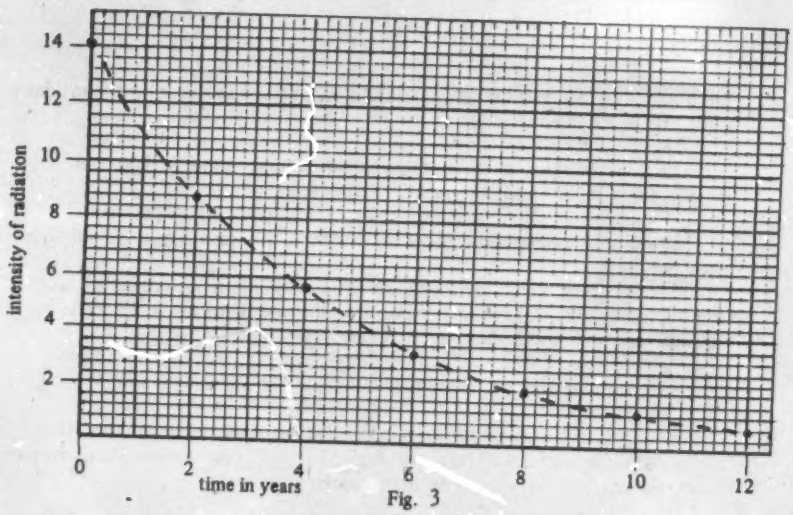
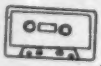


Fig. 3

From the information provided by Fig. 3, estimate the value of the half-life of element X. Your answer should show how you arrived at the value.

(c) State one advantage and one disadvantage to the environment of using Nuclear method of electricity generation.



CASSETTE PROGRAMME. ATOMS AND MOLECULES.

Now listen to the cassette programe your teacher will play to you. Pay close attention so that you can join in the discussion afterwards. Also you will do a short project.

PROJECT

Now that you know something about the atomic theory, design or make models using local materials found near your school or near where your live which show or represent:

a) the structure of the atom
b) different types of chemical bonds
c) the structures of the following;
   1. carbon
   2. hydrogen
   3. nitrogen
   4. chlorine
   5. sodium
   6. oxygen.

If you wish to colour your models Scientists represent carbon with a black colour; hydrogen with red;nitrogen blue; chlorine green; sodium yellow and oxygen white.

SUMMARY OF UNIT

1. An atom is the smallest particle of an element that can take part in a chemical change.

2. A molecule is the smallest part of a compound which can exist in a free and separate state.

3. Mixtures and compounds have different properties.

4. Chromatography is a process of separating a mixture of substances by their different rate of movement over a porous medium caused by a moving solvent.

5. Osmosis is a form of diffusion.

6. Osmosis is the movement of water molecules from a region of high water concentration to a region of low water concentration through a semi-permeable membrane.

7. Electric charges can be stored in one place.

8. Static electricity is when electricity is not moving along a conductor.

9. Current electricity is when electric charges are moving along a conductor.

10. The particle of electricity is the electron.

11. Rubbing causes electrons to be transferred from one object to the other.

12. The atom consists of three particles: the proton, the electron and the neutron.

13. The proton is positively charged while the electron is negatively charged and the neutron is neutral.

14. The atom consists of the nucleus and the electron shell(s).

15. Proton(s) and neutron(s) are found in the nucleus of the atom while the shell(s) is composed of the electron(s) which go round the nucleus.

16. The Atomic Number of an element is the number of protons or electrons in each atom.

17. Atomic mass of an element is the total mass of particles in that element. Atomic mass is measured in atomic mass units.

18. An ion is an atom that has lost or gained an electron(s). A positive ion is a cation and a negative ion is an anion.

19. Atoms of an element that have different numbers of neutrons in their nuclei are known as isotopes.

20. All known elements are listed systematically on the Periodic Chart according to their physical and chemical properties.

21. The spontaneous splitting of the nucleus of an atom with the emission of other particles is known as radio-activity.

22. When radio-activity takes place, particles are emitted. These are the alpha particle, the beta particle and the gamma rays.

23. The time required for radio-activity of an element to fall by half from its observed value at any given moment is known as the half-life of that element.

24. Radio-active materials can benefit man but can also be a health hazard since they cause fatal diseases.

25. Bonding is the chemical joining between elements.

26. Bonding can either be electrovalent (ionic) whereby an atom loses an electron(s) to another atom(s) or covalent whereby two or more atoms share electrons equally.